A Novel Comparative Photothermal Method for Measuring Thermal Diffusivity

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A novel comparative method has been developed at the National Physical Laboratory (NPL) to measure thermal diffusivity of semi-infinite samples without a priori knowledge of the boundary conditions. It is based on photothermal radiometry, and involves the detection of modulated thermal radiance from the target irradiated by a modulated, focused diode laser beam of power 1 W. The technique exploits the fact that the frequency response of the surface temperature modulation scales with thermal diffusivity for a given target geometry (This is a fundamental property of the heat diffusion equation).

The experimental procedure is to measure the frequency responses of the modulated thermal radiance for known and unknown samples placed in the same environment. A computer algorithm searches for the frequency-scaling factor that gives the closest overlap between the frequency responses. The frequency scaling factor is the ratio of thermal diffusivity D(known)/D(unknown). Both the amplitude and phase shift of the modulated thermal radiance signal are retrieved via a lock-in detection, and either can be used in this technique. For a high sensitivity, the laser modulation frequency must span a regime where the thermal diffusion length is comparable with the laser spot size. The overlap between the two-scaled responses should to be maximised and include the region where there is a transition between plane and spherical thermal wave propagation. Different materials have been measured covering a range of thermal diffusivities (platinum, inconel, titanium, pyroceram) and results are presented in this paper. The technique has been incorporated into the NPL fibre-optic based Laser Absorption Radiation Thermometry (LART) system as part of an ongoing development of a multi-thermal property instrument capable of measuring industrial targets.